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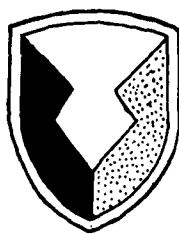
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# COATING and CHEMICAL LABORATORY

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CCL REPORT NO. 145

FINAL REPORT ON COMPATIBILITY OF COOLANTS WITH AUTOMOTIVE  
COOLING SYSTEMS CONTAINING ALUMINUM COMPONENTS

BY

CHARLES B. JORDAN

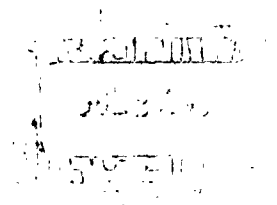
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24 JUNE 1963

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Coating and Chemical Laboratory  
Aberdeen Proving Ground  
Maryland

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# ABSTRACT

The object of this investigation was to determine whether or not current military coolants were compatible with aluminum automotive cooling system components.

Bench corrosion tests were used to predict the effect of the antifreeze compounds on cooling system metals. Several coolant and inhibitor combinations were then evaluated in simulated vehicle circulation units containing aluminum components in conjunction with standard cooling system metals.

It was concluded that the presence of aluminum in military automotive cooling systems would present no immediate incompatibility problem with military coolants. There is an indication that extended use, beyond one year, of military coolants would create a corrosion problem in cast iron/aluminum systems.

## I. INTRODUCTION

Aberdeen Proving Ground, Maryland, was directed by ATAC, OMS Code Number 5010.11.8000.01 dated 26 April 1960, Project TB5-1, to evaluate coolants and coolant inhibitors with automotive cooling systems containing aluminum.

Several current commercial vehicles employ aluminum engines or aluminum cooling system components. In the event that vehicles containing aluminum components should enter the military supply system, it was considered advisable to investigate the compatibility of military coolants with systems containing aluminum components.

CCL Report No. 125, dated 21 June 1962, outlined results of the preliminary bench corrosion and simulated service tests. This report contains the results of all test conducted since the issuance of CCL Report No. 125.

## II. DETAILS OF TEST

### A. Bench Corrosion Tests

Bench corrosion tests were conducted in accordance with the procedure outlined in LSD Report No. 205, dated 26 February 1954. This procedure involves the immersion of a set of six metal test specimens (cast iron, aluminum, copper, brass, steel, solder) in a glass flask containing the test solution. The solution is aerated and refluxed at 180°F. for 192 hours, after which the metal test specimens are examined for evidence and extent of corrosion.

### B. Simulated Service Circulating Unit Tests

This test involves variations of the test outlined in LSD Report No. 205, dated 26 February 1954. The test consists of mechanical units arranged to permit the test solution to be circulated in a closed system at a controlled circulation rate and temperature.

In this investigation the unit contained aluminum or cast iron engine blocks and aluminum or brass radiators. The pump was driven by an electric motor. Tests were conducted at a coolant temperature of 180°F.  $\pm$  5°F.

Tared metal test specimens arranged on a metal rod and inserted into the radiator were removed and examined at regular intervals.

### C. Test Solutions

Aqueous solutions of Specification 0-A-548a antifreeze were tested with and without additional inhibitor meeting Specification 0-1-490. Specification 0-A-548a antifreeze was also tested with a double condensate of borax with 1,2-propylene glycol and 2-butyne-1,4-diol (described in CCL Report # 113), and with an inhibitor combination being developed for military usage containing borax, mercaptobenzothiazole, and disodium phosphate.

Tests were also conducted employing material meeting Specification MIL-C-11755A, Compound, Antifreeze, Arctic-Type.

### III. RESULTS OF TESTS

Results of tests are listed in Tables I thru VII of the Appendix. All solutions performed satisfactorily in the bench corrosion tests (Table I). Additional inhibitor 0-1-490 increased the effectiveness of the Specification 0-A-548a antifreeze (CCL # 125). The double condensate and the borax-MBT-phosphate inhibitors both produced excellent test results (Table VI and VII).

Previous circulating unit tests (CCL Report # 125) had indicated that no difficulty would be encountered in an all-aluminum system. The addition of brass into the system increased initial attack on the aluminum specimens; however, after initial attack no further corrosion occurred. The addition of cast iron into the system produced a possible source of trouble due to attack and deposits on the water pump; however, tests up to 2000 hours were still satisfactory with all test solutions. The addition of the double condensate inhibitor reduced the cast iron attack and, although the final pH and reserve alkalinity values were low, overall ratings were excellent.

The addition of the borax-MBT-phosphate inhibitor to 0-A-548a antifreeze reduced weight loss on all test specimens and greatly improved the overall rating in both the brass/aluminum and cast iron/aluminum systems (Tables VI and VII).

Tests performed on the Arctic antifreeze indicated no problems (Tables II and III). Material meeting MIL-C-11755A gave results comparable to material meeting 0-A-548a. Since MIL-C-11755A is used as packaged, tests were conducted on the concentrated material without the addition of extra inhibitors.

### IV. CONCLUSIONS

Tests conducted during this investigation indicate that in the event vehicles containing aluminum radiator and engine components enter the military supply system no immediate difficulty would be encountered with presently specified coolants and inhibitors. In instances where corrosion may be experienced after extended use, such as illustrated by the cast iron block and aluminum radiator, the addition of one of the newly developed corrosion inhibitors described herein will improve the effectiveness of the prescribed formulations.

### V. RECOMMENDATIONS

Based on the findings of this investigation it is recommended that Federal Specification 0-1-490, Inhibitor, Corrosion, Liquid Cooling System, be revised to include disodium phosphate. This will eliminate the possible corrosion difficulty found in a cast iron/aluminum system.

### VI. REFERENCES

1. Authority: OMS Code 5010.11.8000.01, OTAC, Project TB5-1, dated 26 April 1960.
2. Federal Specification, 0-A-548a, Antifreeze, Ethylene Glycol, Inhibited, dated 30 December 1958.

3. Federal Specification 0-I-490, Inhibitor, Corrosion, Liquid Cooling System, dated 27 November 1957.
4. Military Specification MIL-C-11755A, Compound, Antifreeze, Arctic-Type, dated 17 July 1957.
5. Laboratory Service Division Report No. 205 - Development of a Suitable Laboratory Bench Corrosion Test for Antifreeze Compounds and Inhibitors, dated 26 February 1954.
6. CCL Report No. 113, Improved Multipurpose Corrosion Inhibitor, dated 15 January 1962.
7. CCL Report No. 125, Compatibility of Coolants with Automotive Cooling Systems Containing Aluminum Components - 1st Report, dated 21 June 1962.

## APPENDIX

### Tables

TABLE 1

## BENCH CORROSION SCREENING TESTS

Test No.	1	2
Coolant	50/50 0-A-548a/water	100% MIL-C-11755A
Inhibitor added	Borax/MBT/Phosphate (6 oz to 14 quarts of water)	None
pH before	7.52	7.18
pH after	7.48	7.42
RA before	10.65	7.90
RA after	10.60	7.65
Visual Inspection and Wt change mg/sq cm		
Solder	OK            -.01	Slight pitting   -.07
Steel	OK            -.00	Slight stain     -.01
Aluminum	Slight stain -.05	Heavy pitting   -.16
Cast Iron	Slight stain at contact       -.09	Slight rust       -.05
Brass	Very slight stain           +.02	Slight stain       -.02
Copper	Very slight stain           +.02	Slight stain       +.02

TABLE II

SIMULATED SERVICE TEST - ALUMINUM/BRASS SYSTEM

Metal Component - Aluminum block, brass and aluminum radiators.

Antifreeze - 100% Specification MIL-C-11755A

Added Inhibitor - None

Total Hours of Operation - 2012

Test Coupons - Brass and Aluminum

## RESULTS:

Hours of Operation	0	500	1000	1500	2012
<u>Coupon No (Aluminum)</u>		1A	2A	3A	4A
Visual Appearance		Heavy stain	Heavy stain	Heavy stain	Heavy stain
Wt change mg/sq cm		-0.43	-0.43	-0.52	-0.40
<u>Coupon No (Brass)</u>		1B	2B	3B	4B
Visual Appearance		Very slight stain	Heavy stain	Heavy stain	Heavy stain
Wt change mg/sq cm		+0.01	+0.34	+0.92	+1.38
pH	7.18	7.41	7.28	7.31	7.00
RA	8.0	6.0	6.0	6.0	5.8

REMARKS: In this system, MIL-C-11755A was slightly superior to 0-A-548a.

TABLE III

SIMULATED SERVICE TEST - ALUMINUM/CAST IRON SYSTEM

Metal Component - Cast iron block, aluminum radiator.

Antifreeze - 100% Specification MIL-C-11755A.

Added Inhibitors - None

Total Hours of Operation - 2005

Test Coupons - Cast Iron and Aluminum

**RESULTS:**

Hours of Operation	0	500	1000	1500	2005
<u>Coupon No (Aluminum)</u>		1A	2A	3A	4A
Visual Appearance		Heavy stain	Heavy stain	Heavy stain	Heavy stain
Wt change mg/sq cm		-0.46	-0.46	-0.47	-0.80
<u>Coupon No (Cast Iron)</u>		1C	2C	3C	4C
Visual Appearance		Slight stain	Slight stain	Slight stain	Slight stain
Wt change mg/sq cm		+0.01	+0.02	+0.01	+0.02
pH	7.18	7.25	*7.10	7.21	7.20
RA	8.0	7.1	7.6	7.6	7.6

REMARKS: \* One quart of antifreeze added.

Leaking water pump replaced after 800 hours of operation. New pump OK.  
In this system, MIL-C-11755A was superior to 0-A-548a.

TABLE IV

SIMULATED SERVICE TEST - ALUMINUM/BRASS SYSTEM

Metal Component - Aluminum block, brass and aluminum radiators.

Antifreeze - 50/50 Specification 0-A-548a/water.

Added Inhibitor - None

Total Hours of Operation - 2014

Test Coupons - Brass and Aluminum

## RESULTS:

Hours of Operation	0	500	1000	1500	2014
<u>Coupon No (Aluminum)</u>		1A	2A	3A	4A
Visual Appearance		Heavy stain	Heavy stain	Heavy stain	Heavy stain
Wt change mg/sq cm		-0.82	0.00	-0.55	+1.47
<u>Coupon No (Brass)</u>		1B	2B	3B	4B
Visual Appearance		Slight stain	Moderate stain	Heavy stain	Heavy stain
Wt change mg/sq cm		0.00	-0.44	-0.94	-1.30
pH	7.54	7.47	7.37	7.35	7.10
RA	7.0	6.5	6.0	5.8	5.7

REMARKS: Results of this test were satisfactory after 2000 hours of operation.

TABLE V

SIMULATED SERVICE TEST - ALUMINUM/CAST IRON SYSTEM

Metal Component - Cast iron block, aluminum radiator.

Antifreeze - 50/50 Specification 0-A-548a/water.

Added Inhibitor - None

Total Hours of Operation - 2014

Test Coupons - Cast Iron and Aluminum

## RESULTS:

Hours of Operation	0	500	1000	1500	2005
<u>Coupon No (Aluminum)</u>		1A	2A	3A	4A
Visual Appearance		Heavy stain	Heavy stain	Heavy stain	Heavy stain
Wt change mg/sq cm		-3.28	-2.50	-2.80	-4.71
<u>Coupon No (Cast Iron)</u>		1C	2C	3C	4C
Visual Appearance		Heavy stain	Heavy stain	Heavy stain	Heavy stain
Wt change mg/sq cm		-0.40	-0.40	-0.55	-0.42
pH	7.54	7.54	7.50	7.42	7.31
RA	7.0	7.0	6.5	6.7	7.0

REMARKS: After 2000 hours weight loss on aluminum test specimens was borderline excessive.

TABLE VI

SIMULATED SERVICE TEST - ALUMINUM/BRASS SYSTEM

Metal Component - Aluminum block, brass and aluminum radiators.

Antifreeze - 50/50 Specification 0-A-548a/water.

Added Inhibitor - 75.7% borax, 15.14% mercaptobenzothiazole, 9.16% disodium phosphate (6 oz. to 14 qts. of water)

Total Hours of Operation - 2007

Test Coupons - Brass and Aluminum

## RESULTS:

Hours of Operation	0	500	1000	1500	2000
<u>Coupon No (Aluminum)</u>		1A	2A	3A	4A
Visual Appearance		Slight stain	Slight stain	Slight stain	Slight stain
Wt change mg/sq cm		+0.03	+0.03	+0.02	+0.03
<u>Coupon No (Brass)</u>		1B	2B	3B	4B
Visual Appearance		OK	OK	Very slight stain	Slight stain
Wt change mg/sq cm		+0.04	+0.02	+0.02	+0.02
pH	7.55	7.55	7.58	7.60	7.47
RA	11.0	10.7	9.75	10.25	10.4

REMARKS: Results of this test were excellent.

TABLE VII

SIMULATED SERVICE TEST - ALUMINUM/CAST IRON SYSTEM

Metal Component - Cast iron block, aluminum radiator.

Antifreeze - 50/50 Specification 0-A-548a/water.

Added Inhibitor - 75.7% borax, 15.14% mercaptobenzothiazole, 9.16% disodium phosphate (6 oz to 14 qts of water)

Total Hours of Operation - 1847

Test Coupons - Aluminum and Cast Iron

## RESULTS:

Hours of Operation	0	500	1000	1500	*1847
<u>Coupon No (Aluminum)</u>		1A	2A	3A	4A
Visual Appearance		Slight stain	Slight stain	Slight stain	Slight stain
Wt change mg/sq cm		-0.02	+0.01	+0.10	-0.03
<u>Coupon No (Cast Iron)</u>		1C	2C	3C	4C
Visual Appearance		OK	OK	Very slight stain	Very slight stain
Wt change mg/sq cm		+0.02	+0.08	+0.10	+0.10
pH	7.55	7.55	7.58	7.55	7.56
RA	11.0	9.6	9.8	9.6	9.8

REMARKS: \* Test stopped after 1847 hours of operation due to burned out heating coils in heater. Results of test were excellent.

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